SPECIES COMPOSITION AND ABUNDANCE OF NEONATE SEA TURTLES INHABITING PELAGIC FRONTS NEAR THE FLORIDA CURRENT

Final Report to the National Marine Fisheries Service

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INTRODUCTION

Loggerhead turtles (*Caretta caretta*), which are listed as threatened under the Endangered Species Act of 1973, and green turtles (*Chelonia mydas*), which are listed as endangered, nest on the Atlantic beaches of Florida. During the period of July through October, hatchlings of these species emerge from nests, enter the surf, and disperse at sea. The pelagic phase of sea turtle life history that begins with this dispersal of hatchlings is poorly known. In issues of sea turtle biology and conservation, a working assumption has been that neonate/juvenile sea turtles are passive drifters that inhabit frontal boundaries near major currents in the open ocean. Unfortunately, detailed ecological studies are lacking that would support or refute these hypotheses, allow life-history comparisons between species, or generate indices of abundance in specific geographic regions. Study of pelagic turtles has been difficult, largely due to the inaccessibility of the areas they inhabit.

Recently, we have located a region of the Atlantic Ocean off Florida where young loggerhead turtles can be regularly found (Witherington, 1999). These neonate turtles (estimated to be 5-60 days old) are found within debris lines 20-40 NM from shore near the western boundary of the Gulf Stream. On days of acceptable weather, an average of 12 post-hatchling loggerheads are observed for each hour spent searching (Witherington, 1994 and 1999). This area provides a unique opportunity to study the ecology of pelagic turtles. Because this area lies off nesting beaches where known numbers of both loggerheads and green turtles are entering the sea as hatchlings, there is also an opportunity to test the hypothesis that these species are distributed differently.

Information on the distribution and abundance of neonate loggerhead turtles and green turtles at sea off Florida is valuable to NOAA/NMFS in guiding decisions on potentially harmful Navy operations, oil transport and exploration activities, and sargassum harvest fisheries. A principal goal of this project is to obtain an index of abundance for neonate loggerheads and green turtles inhabiting a specific geographic area off eastern Florida where a number of potentially harmful activities might take place.

OBJECTIVES

1. Determine the species of neonate sea turtles concentrated in areas of oceanic downwelling off Eastern Florida. Address the questions: Are loggerhead turtles and green turtles inhabiting the same areas? Does the proportion of each species leaving nearby beaches predict the proportion of each species found concentrated within areas of oceanic downwelling?

2. Characterize the habitat where neonate sea turtles are found. Address the questions: Are the areas where neonates are found true oceanic fronts (shear boundaries between two water masses)? How accurately do the occurrence of sargassum and the presence of true frontal boundaries predict the presence of neonate sea turtles?

MATERIALS AND METHODS

Study Area and Study Period

I made eight trips to a region of the Atlantic approximately 20 - 40 NM east of Central Florida, near the 40-fathom depth contour and the western wall of the Gulf Stream. Six trips were made from Sebastian Inlet and were focused on a region between North latitudes 27.83° and 28.13° and between West longitudes 079.98° and 080.18°. Two trips were made from Port Canaveral and were focused on a region between North latitudes 28.37° and 28.43° and between West longitudes 079.97° and 080.07°. The eight trips spanned the period of 27 July through 17 October 1998, the period during which hatchlings exit nearby nesting beaches. All observations of pelagic turtles were made in daylight between 0800 and 1800 h.

Habitat Surveys and Physical Oceanographic Measurements

Habitat was surveyed from a low-freeboard, 6.5-m, outboard vessel (R/V Excellent Fishe II). Within the study area, I searched through debris lines at regions of surface-water downwelling. I determined the latitude and longitude of debris lines and made note on their external appearance that would indicate whether the lines were assembled at fronts (as indicated by water color or temperature differences on either side of a north-south oriented line), slicks (as indicated by lines within calm water and with little water color or temperature differences on either side of the line and that are parallel with other widely spaced similar lines), or windrows (as indicated by multiple, closely-set parallel lines that are oriented with wind direction as would result from Langmuir circulation cells). I made additional notes describing density of Sargassum and other debris, width of the debris line, orientation of the debris line relative to wind direction, and weather and sea conditions.

Turtle Capture

After the initial habitat notes and physical oceanographic measurements were made, timed searches for turtles were conducted by observers on the bow of the research vessel (elevation was approximately 2-3 m above the surface) as it moved at idle speed (approximately 2.5 knots) through the center of each debris line. When a turtle was observed, the observer noted the time of the observation, and the geographic position, species, and behavior of the turtle. Observed turtles fell into two categories:

1) Turtles observed but not captured. Data from these turtles were used in addition to data from captured turtles to calculate catch-per-unit-effort and species frequency.

2) Turtles captured by dip net and released. In addition to gathering time, position, and species data, researchers weighed these turtles, measured them for straight-line carapace length (SCL, nuchal to pygal tip), and examined their mouths for the presence of tar. The presence of tar was confirmed when a sample easily dissolved in dichloromethane. Captured turtles were removed from the dip net, processed, marked with a red grease pencil to identify the turtle should it be recaptured (none were recaptured), and released.

Capture Probability Based on Proportion of Species at the Nesting Beach

The probability of encountering the proportion of loggerhead and green turtle post-hatchlings observed in this study was calculated given the proportion of each species leaving nearby nesting beaches as hatchlings during the study period. The hypothesis tested was that loggerhead turtles and green turtles disperse in a similar way, occupy the same pelagic habitat, and are equally observable in the habitat surveyed.

I calculated the binomial probability for the frequency of loggerhead and green turtle captures as

$$p(x) = \left(\frac{n!}{x!\,(n-x)!} \right) (p^{x} q^{n-x})$$

where

p = The probability that a captured post-hatchling would be a green turtle if the hypothesis were true
q = The probability that a captured post-hatchling would be a loggerhead if the hypothesis were true
n = The total number of post-hatchling captures
x = The number of green turtles in n captures

I based both p and q on the proportion of green turtle and loggerhead eggs [(nests) x (clutch size)] on adjacent Florida beaches in 1998 (the Atlantic coast of Florida, 24.5° - 30.7° N; Florida Marine Research Institute, unpublished data).

RESULTS

Description of Habitat

Each habitat sampled had evidence of downwelling and floating debris in long (to 2 NM) contiguous lines or in smaller (0.05 - 0.5 NM), multiple, closely set, parallel lines. Evidence of downwelling commonly included positively buoyant items, such as Sargassum and plastics, submerged below the line of surface debris. Often, masses of submerged medusae were observed to be swimming against an apparent downward current.

Three habitat types (categories of debris lines) were surveyed, and all were found to contain neonate turtles. The first type of habitat occurred where there was evidence of an oceanic front. Fronts were evident as shear boundaries between two water masses having different temperatures, conductivities, and/or current characteristics and a profound degree of downwelling (numerous buoyant objects submerged below the debris line). Debris lines along fronts were oriented north-south (parallel to the axis of the Gulf stream), had slightly turbulent surface water, and often divided two areas of distinctly different water color.

A second type of habitat occurred at slicks. Slicks are produced by the downwelling above and behind the crests of large, slow-moving, internal waves, and in this study were evident as approximately north-south-oriented lines of foam and debris adjacent to or within an area of calm surface water. There was little or no difference between measures of temperature, conductivity, and current, on either side of debris lines thought to be brought together by slicks. No slicks were observed when the wind was greater than 10 knots.

A third type of habitat occurred at aligned, multiple windrows. Windrows are produced by wind-generated Langmuir circulation cells and, in this study, were evident as closely aligned (within 10 m), offset, parallel rows of debris. Windrows were individually oriented approximately parallel with wind direction. Most were collectively oriented approximately north-south, indicating that the windrows may have been fragmented debris lines from slicks or fronts. Windrows were evident when winds were greater than approximately 10 knots.

These three identified habitat types were not analyzed separately because most of the sampling and the majority of the post-hatchling captures were made in slicks. In addition, habitat types were not always readily distinguishable based upon the limited physical oceanographic measurements taken, and in many cases, the debris lines sampled appeared to have features of more than one habitat type. All debris lines were located within a region of persistent fronts where the current grades from sluggish and variable as far as 18 NM offshore to a comparatively swift 3.5-kt northerly current in the Gulf Stream 35 NM offshore. An identified habitat type often changed during attempts to capture post-hatchling turtles. Fronts and slicks were commonly observed to break up into windrows when the wind became greater than 10 knots.

Captures and Catch-per-unit-effort (CPUE)

A total of 106 post-hatchling sea turtles were observed. Of these, 89 were loggerheads that were brought on board the vessel, one was a green turtle brought on board, 15 were loggerheads observed but not captured, and one turtle not captured was not identified to species. One captured loggerhead was initially observed when a timed search for turtles was not being conducted and therefore does not count toward calculations of CPUE. Total recorded search time in debris lines was 534 minutes during which observations of 104 loggerheads and one green turtle were made (one loggerhead post-hatchling each 5.13 minutes and one green turtle each 534 minutes).

The one green turtle captured represented approximately 1% of the observations of post-hatchlings identified to species. I conducted a test of binomial probability to determine whether the observation of one green turtle among 105 turtle observations has a likelihood of less than 5%. In the formula presented in the methods, the number of green turtle encounters (x) equals one, and the proportion of loggerhead turtles among both loggerheads and green turtles that had departed the nearby coast (q) was 0.9245 (Florida Marine Research Institute, unpublished data). The probability $p(x)$ that 104 loggerheads and one green turtle would be observed in an assemblage of neonate sea turtles with species proportions equal to the proportions of the two species leaving the Atlantic coast of Florida was 0.0023. Thus, the hypothesis that neonate loggerhead turtles and green turtles disperse in a similar way, occupy the same pelagic habitat, and are equally observable in the habitat surveyed, is rejected (note that only one condition need be false in order to reject the hypothesis).

Size and Activity

Loggerhead post-hatchlings in the present study ($\overline{x}$ = 45.73 mm SCL, SD = 2.0 mm, range = 41.34 - 50.31 mm, n = 89; $\overline{x}$ = 21 g in weight, SD = 2.4 g, range = 16.5 - 24 g, n = 44) were on average slightly larger than loggerhead hatchlings from nearby nesting beaches ($\overline{x}$ = 44.5 mm SCL, n = 79, Witherington 1994 b). The green turtle measured 54.64 mm SCL and weighed 27.0 g.

The modal behavior of post-hatchling loggerheads when first observed was a fetal tuck (71% of 104 observations). I observed turtles in a fetal tuck to float motionless with the ventral surface of the front flippers in full contact with and pressed flat against the lateral carapace margin and with the distal webs of the rear flippers overlapping, thereby concealing the tail (described by Witherington 1994 b, 1995). The second most common behavior was the dog paddle (17%). Turtles in a dog paddle moved all four flippers in an alternating pattern similar to exaggerated crawling movements. During a dog paddle the head was raised above the surface, and among turtles that were observed closely, there were buccal-pharyngeal indications that a breath was taken. Dog paddling resulted in little forward movement. The third most frequent behavior was the rear-flipper kick pattern (12%). Turtles showing this behavior were in a position similar to the fetal tuck except that the rear flippers moved with a rhythmic, simultaneous stroke to propel the turtle forward at the surface (described by Davenport and Clough 1986). I considered similar movements -- employing single rear flippers and occasional extensions of a single front flipper (as might be expected from steering movements) -- to be part of the rear-flipper kick pattern.

The only green turtle observed was under the water's surface in a powerstroke pattern, actively swimming forward using its front flippers only. Unlike all of the loggerhead turtles captured, the green turtle attempted to evade net capture by repeated diving and vigorous swimming.

Prevalence of Plastic and Tar

Of 89 post-hatchling loggerheads sampled, nine were found to have tar adhering to the inner or outer surface of their jaws. One loggerhead with tar in its jaws also had a strip of translucent plastic adhering to the tar. The captured green turtle showed no signs of plastic or tar ingestion. These frequencies are lower than the 63% incidence of tar and the 17% incidence of plastic recorded in either mouth or lavage samples of loggerheads (n=103) captured in 1993 (Witherington 1994 a).

DISCUSSION AND CONCLUSIONS

Habitat Description

Numerous features make the area sampled likely to contain habitat for post-hatchling sea turtles. The most important of these features is the continental edge of the Gulf Stream, where a persistent front collects debris lines. Off the central Florida peninsula, the front occurs in an area where water depth changes sharply from approximately 50 m to 200 m within a distance of five NM. This bathymetric feature may cause internal waves to refract and slow, thereby creating an area where north-south oriented slicks frequently occur. Formation of slicks east of central Florida may be more profound during the late-summer sea turtle hatching season when sea conditions are often calm and the local thermocline (in which internal waves travel) is distinct. Each of these phenomena create lines of downwelling where debris and biota collect (Ashjian et al. 1994) within frenzied-swimming distance of the hatchlings that leave eastern Florida nesting beaches.

In addition to creating debris lines, currents are also important in transporting neonate turtles that are within debris lines. Most of the turtles I observed were being transported north at approximately 10 - 80 NM/day. This observation is in keeping with the hypothesis that loggerheads from Florida become entrained in the North Atlantic Gyre soon after leaving the nesting beach.

Weather conditions in the survey area and during the survey period greatly affected the researcher's abilities to find debris-line habitat and the turtles within it. In this area during the summer, winds are usually light (<10 knots) and variable -- conditions that make debris lines longer, more distinct, and easier to search for turtles. In winds greater than 10 knots, debris lines were observed to break up into more widely separated and difficult-to-survey windrows. It is not known how debris-line fragmentation may affect the dispersal of neonate turtles and their ability to forage.

The frequency of turtles observed in debris lines was also aided by the proximity of the habitat surveyed to densely nested beaches. Habitat within the study area is immediately downstream from the majority of loggerhead hatchling production in the western hemisphere (located in eastern Florida between 26.0° and 28.5° N, Turtle Expert Working Group 1998) and the vast majority of turtles observed in this study probably originated from these beaches.

Abundance and Species Composition

Post-hatchling loggerheads were common in the debris lines surveyed within the study area. Capture rates in this study were similar to loggerhead capture rates in the previous year (Witherington, 1999). As in the previous study, loggerhead densities in debris lines indicate that the distribution of neonate loggerheads is not random and that they are greatly concentrated within the habitat surveyed.

As was found in a study of post-hatchling loggerheads captured in 1993 and 1997 (Witherington 1994 b and 1999), captured post-hatchling loggerheads were slightly larger than hatchlings leaving the nesting beach. Because feeding and growth occur after the initial swimming frenzy and not during the few days that yolk reserves are retained (Kraemer and Bennett 1981) and because observed turtles did not display frenzied swimming, I estimate that the post-hatchlings in debris lines were approximately 5-30 days old. I reason that the captured turtles were within one or two days of their entrainment in the Gulf Stream (given the approximate transport time from the southern reach of the nesting range). If true, larger post-hatchlings probably swam out their frenzy period, began foraging, and grew substantially in the area of ocean between the western Gulf Stream and the Florida peninsula during a period of days or weeks. The similarity of loggerhead-capture seasonality (Witherington 1999) to the July-October hatching season indicates that the average lag time between hatchling emergence from nests and entrainment in the Gulf Stream is less than one month.

Only one neonate green turtle was captured (1% of 105 turtle observations) despite the expectation that approximately 7.6% of the hatchlings dispersing from nearby beaches were green turtles. Because this paucity of captures was not likely due to chance alone, neonate green turtles may differ from loggerheads in the areas they inhabit, in how they are distributed in this habitat, in their behavior (e.g., greater activity than loggerheads), in their ability to conceal themselves from observers, or in any combination of these. A similar conclusion was drawn from the previous year's study (Witherington 1999).

Behavior of Pelagic Post-hatchling Loggerheads and Green Turtles

Evidence from the present study shows post-hatchling loggerheads to be low-energy, float-and-wait foragers occupying pelagic habitats that include collections of floating debris. The most common behaviors among captured loggerheads appeared to be those requiring minimal energy: the fetal tuck, in which there is little or no movement, and the rear-flipper-kick pattern, in which there is relatively limited movement of the rear flippers only. Limiting activity may function both to conserve energy for growth and to conceal turtles from predators.

The one green turtle captured behaved differently from the loggerheads observed. Rather than floating in a relatively inactive state, the green turtle was vigorously swimming when found and actively evaded net capture until it was caught by a swift scoop of the net as it surfaced to breathe between dives. Although this one sample is minimal evidence, these behavioral observations support the hypothesis that neonate green turtles occupy the same debris lines as loggerheads, but because of behavioral differences, green turtles are less likely to be observed.

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